Waste Pit 1

Because waste slurries were filtered or calcined to remove water before they were placed into Pit 1, Waste Pit 1 was a dry pit. Pit 1 primarily received neutralized waste, filter cakes, vacuum-filtered sludge from production activities, magnesium fluoride slag, scrap graphite, and contaminated brick. In 1959, Waste Pit 1 was closed and covered with clean fill. Waste inventory records indicate that Waste Pit 1 contained 1,075 metric tons of uranium (Advanced Sciences, Inc. and ORAUT-TKBS-0017-2).

Waste Pit 2

Waste Pit 2 was a dry pit that received primarily waste filter cakes, vacuum-filtered production sludge, magnesium fluoride slag, scrap graphite, contaminated brick, and concentrated raffinate residues. In 1964, Waste Pit 2 was closed and covered with clean fill. Waste inventory records indicate that Waste Pit 2 contained 175 metric tons of uranium (Advanced Sciences, Inc. and ORAUT-TKBS-0017-2).

Waste Pit 3

Waste Pit 3 was the first waste pit built specifically for settling solids from liquid waste streams. Primarily, it was used to hold lime-neutralized raffinate slurries and contaminated surface-water runoff. After Waste Pit 2 was filled, Waste Pit 3 received vacuum-filtered production sludge, neutralized liquid from process systems, neutralized refinery sludge, and cooling water from heat treatment operations. During the late 1960s, large quantities of neutralized residues from acid leaching of uranium-bearing magnesium fluoride slag were pumped into Waste Pit 3. In 1973, fill materials (including filter cake, slag leach residue, lime sludge, and fly ash) were placed in Waste Pit 3 and construction activities were initiated to cover the waste with soil. Soil coverage was completed in 1977. Waste inventory records indicate that Waste Pit 3 contained 846 metric tons of uranium (Advanced Sciences, Inc. and ORAUT-TKBS-0017-2).

Waste Pit 4

Waste Pit 4 received solid wastes such as process residues (filter sludge, raffinates, graphite, magnesium fluoride slag, and pyrophoric uranium-bearing materials), scrap uranium metal, off-specification intermediate uranium products and residues, thorium metal and residues, and contaminated ceramics. Thorium metal and residues were placed in Waste Pit 4 when additional metal recovery was not economically feasible. Waste Pit 4 disposal activities were terminated in 1985 and the pit closed in 1986. Also in 1986, cover activities were initiated. Waste inventory records indicate that Waste Pit 4 contained 2,203 metric tons of uranium and 74 metric tons of thorium (Advanced Sciences, Inc. and ORAUT-TKBS-0017-2).

Waste Pit 5

Waste Pit 5 was a settling basin for slurries, including neutralized raffinates, slurries from acid leaching of uranium-bearing slags, and sump slurries that were generally filtered to remove solids. Supernatant and sludge, produced by the co-precipitation of thorium wastes with barium carbonate and aluminum sulfate and the precipitation of uranium with calcium oxide, was disposed in Waste Pit

5. The discharge of slurried waste materials into Waste Pit 5 ended in 1983 and its use as a settling basin ended in 1987. Waste inventory records indicate that Waste Pit 5 contained 527 metric tons of uranium and 72 metric tons of thorium (Advanced Sciences, Inc. and ORAUT-TKBS-0017-2).

Waste Pit 6

Because Waste Pit 6 had a thin membrane liner that could be damaged by coarse materials, Waste Pit 6 received only non-coarse, non-pyrophoric materials (this excludes uranium and thorium in metallic form), which included magnesium fluoride slag, process residues, and filter cakes from vacuum filtering operations. In addition, the pit was used to store extrusion residue and heat treatment quench water. Use of Waste Pit 6 ended in 1985; it's currently covered by water. Waste inventory records indicate that Waste Pit 6 contained 1,432 metric tons of uranium (Advanced Sciences, Inc. and ORAUT-TKBS-0017-2).

Burn Pit

The Burn Pit was initially excavated in 1957 to obtain clay for lining Pits 1 and 2. Subsequently, combustible materials, including pyrophoric and reactive chemicals, oils, and other low-level contaminated combustible materials, were burned in this pit. In addition, laboratory chemicals were discarded in the Burn Pit. In 1968, the Burn Pit was backfilled, and in 1984, all of the contents of the Burn Pit were transferred to Waste Pit 4 (EPA/ROD/R05-95/286, Advanced Sciences, Inc).

Solid Waste (Sanitary) Landfill

The solid waste (sanitary) landfill was located near the waste pits in the northwest corner of the Waste Storage Area and received non-burnable waste, non-radioactive waste, and non-radioactive construction rubble. The landfill was also known to contain small quantities of non-radioactive asbestos (Advanced Sciences, Inc. and ORAUT-TKBS-0017-2).

Fly Ash Disposal Areas and Southfield

The Fly Ash Disposal Areas are located southwest of the production area. Fly ash resulting from the coal-fired boiler plant was loaded into dump trucks and transported to the disposal area. Because fly ash dust was controlled by spreading oils containing uranium over the fly ash, about 1,000 kg of uranium was present in the Fly Ash Disposal Areas.

The area known as the Southfield is assumed to be encompassed by the Disposal Areas due to the close proximity of those areas. The Southfield reportedly served as the repository for below-ground disposal of low-level radioactive construction rubble.

Clear Well

The Clear Well received surface runoff from the waste pits as well as some flow-through liquids. It was used as a final settling basin prior to runoff discharge into the Great Miami River.

### 5.2.9 Thorium Processing and Storage

Periodically, small amounts of thorium (in comparison to the uranium output) were processed at FMPC. In the 1950s, thorium metal was produced for the nuclear aircraft program which was canceled in 1961. During the mid-1960s, thorium oxides were produced for the Light Water Breeder Reactor Program (Parsons, 1993). Purified thorium nitrate, to support various processes at the FMPC and other facilities, was produced from 1964 through 1979. All thorium processing at the FMPC ended in 1979.

In general, thorium production steps were similar to those followed in uranium production. Thorium ore was dissolved, purified, and turned into a final product. The involvement of FMPC in thorium processing is described below. Final products included purified thorium nitrate tetrahydrate solution, solid thorium compounds, and metal.

Starting in 1972, in addition to the processing of thorium, the FMPC served as DOE's thorium materials repository. Approximately two-thirds of the material in the repository was processed onsite at FMPC.

Pilot Plant

Early thorium operations at the Pilot Plant included studies and demonstrations of thorium processes. From April through June of 1954, extraction studies of mantle grade thorium nitrate were performed. In addition, a project to demonstrate calcium reduction of thorium oxide to thorium metal powder took place during July 1956. Additionally, a unit was installed in April 1955 for the preparation of thorium oxalate pellets and thorium chloride. Later, a unit for the production of thorium chloride from thorium oxalate was installed in October 1955 and a project was initiated during July 1956 to demonstrate a process for calcium reduction of thorium oxide to thorium metal powder (Parsons, 1993). No production data is available for the early Pilot Plant thorium processes (Dolan, 1988).

From 1964 through 1979, thorium ores, crushed thoria pellets, thorium oxalate, as well as other thorium materials, were processed through the Pilot Plant thorium digestion system and extraction system to produce a purified thorium nitrate (TNT) solution to be used as feed for other thorium production streams. The TNT solution was also shipped as a final product to other facilities, including Nuclear Fuel Services, Weldon Springs, and Mallinckrodt. The digestion system consisted of a large tank into which the material to be digested had to be manually dumped. The digestion and extraction systems were used intermittently; some years the throughput rate was as high as one ton per day of purified TNT solution, in contrast to other years when the systems did not operate at all or operated sporadically. Production records indicate that 790.4 metric tons of thorium in the form of purified TNT solution was produced from 1966 to 1973. Production rates for other years are unavailable (Hill, 1989).

Using purified TNT solution as the feed material for the thoria gel process, the Pilot Plant was used to produce thoria gel from 1964 to 1970. Carbon dioxide and aqueous ammonia were added to the TNT solution to cause thorium hydroxide to precipitate from the solution. The thorium hydroxide was then slurried with water and aqueous ammonia, filtered on plate and frame filter, and then dried to form thoria gel (thorium hydroxide). This thorium hydroxide was then shipped to another location for calcining and the final product was shipped to the customer. The total estimated production of thoria gel is estimated to be 686 metric tons (Hill, 1989).

TNT crystal production occurred as a short term test in 1966. The process required the boiling of purified thorium nitrate tetrahydrate to a defined concentration. The resulting molten salt was then fed onto a conveyer where it crystallized and was drummed at the end of the conveyor. Total production during the test period was 425 kilograms of crystals (Hill, 1989).

Thorium metal was produced in the Pilot Plant from 1969 to 1971. A modification of the process used in Plant 9 during the 1950s was employed in the Pilot Plant when zinc fluoride was used instead of zinc chloride for the reduction of thorium tetrafluoride to thorium metal; the metal quality was much improved by this change. In the process, thorium tetrafluoride was precipitated by adding hydrofluoric acid to the thorium nitrate tetrahydrate solution. The resulting thorium tetrafluoride was filtered, dried in a shelf pre-dryer, and re-dried in a furnace. The dried thorium tetrafluoride was then milled and blended with calcium metal and zinc fluoride and placed in a furnace to reduce the thorium tetrafluoride to thorium metal. The resulting zinc-thorium derby was cleaned, de-zinced, and sawed into the final product. Production records indicate that 809 derbies (51 metric tons) were produced by this process (Hill, 1989).

From 1971 to 1976, thorium oxalate was produced by the Pilot Plant using a precipitation process where oxalic acid was added to a purified thorium nitrate tetrahydrate solution to form a wet precipitate which was filtered on a plate and frame filter. After filtering, the thorium oxalate solution was packaged and shipped to another location for calcining to thorium oxide. Production records indicate that 153 metric tons of thorium oxalate was produced (Hill, 1989).

From 1977 to 1979, thorium nitrate was stabilized into thorium gel. This occurred when the need for thorium materials decreased to a level at which no other production was required. The process was similar to that used earlier to produce thoria gel. Production records indicate that 350 metric tons of thoria gel was produced by this process (Hill, 1989).

<u>Plant 1</u>

Beginning in 1956, Plant 1 processed Canadian ore, which contained thorium. Processing Canadian ore included crushing, grinding, and sampling the ore in preparation for further processing at the Pilot Plant. In addition to processing Canadian ore, Plant 1 supported sampling and analysis of material for on-site processes as well as that received from other sites. Some of this material would have contained thorium compounds.

<u>Plant 2/3</u>

In 1968, as a short-term thorium production test, Plant 2/3 was briefly used to produce thorium nitrate crystals and thorium oxide. While few details are available regarding this process, it is known that thorium nitrate crystals were produced in a denitration pot in Plant 2/3. Interviews with long-time employees suggest that crystal production was a short-term operation that likely amounted to the production of a single pot of crystals. Other FMPC records discuss the production of thorium oxide in Plant 2/3 by denitration, re-digestion, and drying (Hill, 1989).

Plant 4

Plant 4 processed thorium oxide from Plant 9 into dried thorium tetrafluoride. The thorium tetrafluoride was then returned to Plant 9 and was used to produce thorium metal. This hydrofluorination process took place during 1954; and due to mechanical difficulties in the hydrofluorination Bank 7, occurred for only a short amount of time (Hill, 1989).

Plant 5

No known thorium activities occurred at Plant 5.

Plant 6

In 1959, in order to process pyrophoric thorium residues that were stored onsite and were the cause of numerous fires at FMPC, a proposal was made to perform alterations to the uranium sludge furnace in Plant 6 to allow for thorium oxidation (NLC, 1959). Thorium residues were oxidized in the Plant 6 furnace from early 1960 to mid-1963. In 1970, thorium derbies were cut using a shear (Cavendish, 1970).

Plant 7

No known thorium activities occurred at Plant 7.

Plant 8

Thorium hydroxide production occurred in Plant 8 for a six month period in 1966. Thorium tetrafluoride was reverted to thorium hydroxide by heating it in a reverter tube with hydrofluoric acid. Approximately 59 metric tons of thorium hydroxide was produced by this method (Hill, 1989).

From 1969 to 1971, thorium residues were processed in Plant 8 converting the residues to thorium hydroxide before their return to the production stream. Residues were digested in hydrochloric acid and then filtered in a rotary vacuum filter. The filtrate was then precipitated and mixed with oxalic acid. This produced thorium oxalate which was then converted by a sodium hydroxide solution and filtered to produce thorium hydroxide. The resulting filter cake was then calcined in the uranium ammonium phosphate furnace and shipped to the Pilot plant digestion system. Approximately 310 metric tons of thorium hydroxide was produced by this method (Hill, 1989).

Plant 9

Plant 9 was originally designed and constructed as a thorium metal production plant. Thorium was first introduced to the Plant 9 system on January 26, 1954. By February 15, 1954, thorium metal production operations began and continued through 1955, possibly into 1956, although production records are unavailable for 1956 (Parsons, 1988). The process began with the dissolution of solid thorium nitrate tetrahydrate (TNT) in nitric acid. Hydrofluoric acid was then added to the solution to precipitate a wet thorium tetrafluoride. The thorium tetrafluoride was then dried, pulverized, and blended with calcium metal and zinc chloride. This mixture was placed in a furnace to be co-reduced by the calcium to form a zinc-thorium derby which was then de-zinced and re-melted in a vacuum furnace. This resulted in a 500 kilogram thorium metal ingot ready to be machined for the final product. The thorium chips and turnings that remained after the machining was completed were washed in nitric acid, dried, and then pressed into briquettes and returned to the production process to be re-melted. (Hill, 1989)

In 1954, Plant 9 also produced thorium oxide from thorium nitrate tetrahydrate and oxalic acid. The thorium oxide was transported to Plant 4, hydrofluorinated to produce thorium fluoride, and then returned to Plant 9 to produce thorium metal. A total of 380 metric tons of thorium metal is estimated to have been produced in Plant 9 (Hill, 1989).

Thorium Storage

Starting in 1972, FMPC became DOE's thorium materials repository. The stored materials were out-of-specification production runs, process by-products, or excess materials returned from the downstream production facilities when the materials were no longer required (Parsons, 1993). As of 1989, more than 13,000 containers of thorium (1,100 metric tons) compounds were stored onsite in Buildings 64, 65, 67, and the Pilot Plant.

### 5.2.10 Summary of Key FMPC Facilities

Table 5.2 summarizes the key FMPC processes, as well as the buildings and dates of operation.

**Table 5-2: Key FMPC Facilities, Operations, and Dates of Operation**

| Buildings | Key Facilities | Dates of Operation |
|---|---|---|
| Pilot | **Pilot Plant:** In October 1951, the Pilot Plant became the first plant to operate. Initially it served as an operating prototype of all phases of FMPC's uranium metal production process. Later, the principal functions included converting uranium hexafluoride into uranium tetrafluoride (green salt) for use in the metal production process and purifying and converting thorium nitrate solution into various thorium compounds. Primary radionuclides included uranium and thorium isotopes, including progeny. | 1951-1989 |
| 1 | **Plant 1:** The Sampling Plant supported operations throughout the site. Its principal capabilities were shipping, receiving, sampling, and storing large amounts of depleted, normal, and enriched uranium materials in open and covered storage areas; drying, crushing, milling, grinding, and classifying feed materials for processing; digesting enriched residues assaying 5% to 20% uranium-235 in geometrically safe equipment; and opening un-irradiated fuel pins containing enriched uranium dioxide pellets. Primary radionuclides included isotopes of uranium and thorium. | 1953-1989 |
| 2/3 | **Plant 2/3:** The Refinery converted the government stockpile of natural uranium ore concentrates to uranium trioxide. In 1962, site management placed Plant 2/3 on standby while refining operations were consolidated at the Weldon Spring site near St. Louis, Missouri. For the next few years, Plant 2/3 processed only scrap feed. Then in 1966, Plant 2/3 was reactivated following the shutdown of Weldon Spring. | 1953-1989 |

| Table 5-2: Key FMPC Facilities, Operations, and Dates of Operation | | |
|---|---|---|
| **Buildings** | **Key Facilities** | **Dates of Operation** |
| | In 1988, the refinery operated intermittently in a sequential campaign mode to convert enriched recycled materials to oxide. Primary radionuclides included isotopes of uranium and thorium. | |
| 4 | **Plant 4:** The Green Salt Plant produced green salt (uranium tetrafluoride) from uranium trioxide which was either produced in the refinery or recycled from other DOE sites. Due to a decline in demand, the facility operate sporadically from the early 1970s to 1980, when the process was restarted. Primary radionuclides included isotopes of uranium and some isotopes of thorium. | 1953-1989 |
| 5 | **Plant 5:** Using a thermite-type reaction with magnesium, the Metal Production Plant converted the uranium tetrafluoride that was produced in Plant 4 and the Pilot Plant into uranium metal. Primary radionuclides included isotopes of uranium. | 1953-1989 |
| 6 | **Plant 6:** At the Metals Fabrication Plant, uranium metal products were heat-treated to improve their strength and grain structure. Some of these products were shipped offsite for extrusion. The extruded tubes were returned to the Metals Fabrication Plant to be machined into final products for shipment to other DOE sites. Primary radionuclides included isotopes of uranium and thorium. | 1952-1989 |
| 7 | **Plant 7:** The Hexafluoride Reduction Plant converted uranium hexafluoride to green salt using the same process as the Pilot Plant. The green salt was used in Plant 5 to produce uranium metal. After only two years of operation, the U.S. Atomic Energy Commission (AEC) ordered the shutdown of Plant 7 because a similar processing plant was operating in Paducah, Kentucky. For the next 13 years, site management considered several proposals for the idle facility, but none of the proposals were accepted. In 1969, all equipment was sold and the building was used to store drums of green salt and empty containers. Primary radionuclides included isotopes of uranium. | 1954 – 1956 |
| 8 | **Plant 8:** During the 1970s, Plant 8 operated on an as-needed basis. In Plant 8, recycled residues and scrap from uranium processing were upgraded before being sent to the refinery for uranium extraction. In addition to recycle functions, the plant equipment was used to treat enriched uranium residues. Primary radionuclides included isotopes of uranium and thorium. | 1953-1989 |
| 9 | **Plant 9:** The Special Products Plant was originally designed and constructed as a thorium metal production plant. Because thorium processing was infrequent and occurred in small amounts, the primary function of the Special Products Plant became casting larger ingots than those produced in Plant 5 and machining uranium metal pieces for extrusion. Primary radionuclides included isotopes of uranium and thorium. | 1954-1989 |
| Silos | **Silos 1 and 2:** The K-65 Silos received radium-bearing residues from uranium ore | 1955-2005 |

| Table 5-2: Key FMPC Facilities, Operations, and Dates of Operation | | |
|---|---|---|
| **Buildings** | **Key Facilities** | **Dates of Operation** |
| | processing. The K-65 ore was not processed prior to receipt, resulting in high levels of radium residue. Primary radionuclides included radium and radium progeny.<br><br>**Silo 3:** In the 1950s Silo 3 received waste residues, known as cold metal oxides, which were generated during extraction operations involving uranium concentrates. The residues in Silo 3 are substantially different from those in Silos 1 and 2. First, Silo 3 residues are dry (~10% moisture) while K-65 material is wet (~30% moisture). Second, while Silo 3's radiological constituents are similar to those in Silos 1 and 2, some radionuclides such as radium are present in much lower concentrations.<br><br>**Silo 4:** Never used | |
| Waste Pits | **Pit 1:** Waste Pit 1 received neutralized waste filter cakes, production plant sump cakes, depleted slag, scrap graphite, contaminated brick, and sump liquor. Most waste was dry. Primary radionuclides include isotopes of uranium. | 1952-1957 |
| | **Pit 2:** Waste Pit 2 received dry, low-level radioactive wastes similar to Pit 1. Primary radionuclides include isotopes of uranium and thorium. | 1957-1964 |
| | **Pit 3:** Waste Pit 3 operated as a settling basin, receiving wet waste streams consisting of lime-neutralized radioactive raffinate from the recovery plant (Plant 8) and the general sump. Primary radionuclides include isotopes of uranium and thorium. | 1959-1968 |
| | **Pit 4:** Waste Pit 4 primarily received dry, low-level radioactive waste such as process residues, trailer cakes, slurries, raffinates, graphite, non-combustible trash, and asbestos. Primary radionuclides include isotopes of uranium and thorium. Almost 75% of the thorium waste is in this pit. | 1960–1986 |
| | **Pit 5:** Waste Pit 5 received liquid slurries similar to those in Pit 3 from the Refinery (Plants 2/3) and the Recovery plant (Plant 8). Primary radionuclides include isotopes of uranium and thorium. | 1968-1983 |
| | **Pit 6:** Pit 6 received dry, solid, non-pyrophoric waste such as green salt, filter cakes, and process residues. Primary radionuclides include isotopes of uranium. | 1979-1985 |

| Table 5-2: Key FMPC Facilities, Operations, and Dates of Operation | | |
|---|---|---|
| **Buildings** | **Key Facilities** | **Dates of Operation** |
| | **Burn Pit:** The Burn Pit was used to dispose of laboratory chemicals and to burn pyrophoric and reactive chemicals, oils, and other low-level mixed combustible materials. No radioactive inventory is available. However, it likely that the Burn Pit contains both uranium and thorium. | 1957-1968 |

**Note: Information for this table was obtained from *Remedial Investigation of the Feed Material Production Center—Part 1: Evaluation of Current Situation* by Advanced Sciences, Inc. and from the DOE Fernald Closure Project website.**

## 5.3 Radiological Exposure Sources from FMPC Operations

Radiation exposure at FMPC came from both internal and external sources. Although the primary isotope of interest was uranium, there were significant exposure potentials from the uranium progeny, especially radium. Due to the nature of processing activities at FMPC, there were significant opportunities for airborne exposure to uranium and thorium. The uranium, thorium, and associated progeny gave rise to alpha, beta, and photon exposures. Although neutron exposure is not normally a hazard associated with uranium, some compounds of uranium, such as uranium fluoride, can emit neutrons.

### 5.3.1 Alpha Particle Emissions

The primary alpha particle-emitting isotopes at FMPC were derived from uranium, thorium, and their progeny. Additional alpha-emitting radionuclides were introduced when FMPC accepted “recycled” uranium. The recycled uranium also contained transuranic contamination. Table 5-3 shows the alpha-emitting nuclides and their primary alpha energies.

| Table 5-3: FMPC Alpha-Emitting Radionuclides | |
|---|---|
| **Isotope** | **Energy (MeV)** |
| Uranium-234 | 4.72(28%), 4.77(72%) |
| Uranium-235 | 4.37(18%), 4.4(57%), 4.58(8%) |
| Uranium-236 | 4.44((24%), 4.49(76%) |
| Uranium-238 | 4.15(25%), 4.2(75%) |
| Thorium-232 | 3.95(24%), 4.01(76%) |
| Thorium-230 | 4.62(24%), 4.68(76%) |
| Thorium-228 | 5.34 (28%), 5.43(71%) |
| Thorium-227 | 5.76(21%), 5.98(24%), 6.04(23%) |
| Radium-226 | 4.6(6%), 4.78(95%) |
| Radium-224 | 5.45(6%), 5.68(94%) |
| Radium-223 | 5.61(26%), 5.71(54%), 5.75(9%) |
| Radon-222 | 5.49 |

| Table 5-3: FMPC Alpha-Emitting Radionuclides | |
|---|---|
| **Isotope** | **Energy (MeV)** |
| Radon-220 | 6.29 |
| Radon-219 | 6.42(8%), 6.55(11%), 6.82(81%) |
| Protactinium-231 | 4.95(22%), 5.01(24%), 5.02(23%) |
| Actinium-227 | 4.86(0.18%), 4.95(1.2%) |
| Bismuth-213 | 5.55 (0.16%), 5.87 (2%) |
| Bismuth-211 | 6.28(16%), 6.62(84%) |
| Polonium-218 | 6.0 |
| Polonium-216 | 6.78 |
| Polonium-215 | 7.38 |
| Polonium-214 | 7.69 |
| Polonium-212 | 8.78 |
| Polonium-211 | 7.45(99%) |
| Polonium-210 | 5.305 |
| Astatine-218 | 6.65(6%), 6.7(94%) |
| Plutonium-238 | 5.46(28%), 5.50(72%) |
| Plutonium-239 | 5.11(11%), 5.16(88%) |
| Plutonium-240 | 5.12(24%), 5.17(76%) |
| Americium-241 | 5.44(13%), 5.49(85%) |
| Neptunium-237 | 4.78(75%), 4.65(12%) |

### 5.3.2 Beta Radiation Fields

As with the alpha emitters, the majority of the beta exposure came from uranium, thorium, and their progeny. In addition, when recycled uranium was introduced, technetium-99 and transuranics were also introduced. Table 5-4 shows the FMPC beta-emitting radionuclides and the corresponding maximum beta energy in units of MeV.

| Table 5-4: FMPC Beta-Emitting Radionuclides | |
|---|---|
| **Isotope** | **Maximum Beta Energy (MeV)** |
| Thorium-234 | 0.103(21%), 0.193(79%) |
| Thorium-231 | 0.140(45%), 0.220(15%), 0.305(40%) |
| Protactinium-234m | 2.29(98%) |
| Protactinium-234 | 0.53(66%), 1.13(13%) |
| Actinium-227 | 0.043 |
| Actinium-228 | 1.18(35%), 1.75(12%), 2.09(12%) |
| Francium-223 | 1.15 |
| Radium-228 | 0.055 |
| Bismuth-214 | 1.0(23%), 1.51(40%), 3.26(19%) |
| Bismuth-212 | 1.55(5%), 2.26(55%) |
| Bismuth-211 | 0.6(0.28%) |
| Bismuth-210 | 1.161 |

**Table 5-4: FMPC Beta-Emitting Radionuclides**

| Isotope | Maximum Beta Energy (MeV) |
|---|---|
| Lead-214 | 0.65(50%), 0.71(40%), 0.98(6%) |
| Lead-212 | 0.346(81%), 0.586(14%) |
| Lead-210 | 0.016(85%), 0.061(15%) |
| Thallium-208 | 1.28(25%), 1.52(21%), 1.80(50%) |
| Thallium-207 | 1.44 |
| Technetium-99 | 0.292 |
| Plutonium-241 | 0.021 |

### 5.3.3 Neutron Exposures

There were no documented neutron exposures at FMPC. However, the use of uranium hexafluoride and uranium fluoride can generate neutrons through an alpha-neutron reaction between the uranium and the fluorine. Neutrons can also arise from higher enriched uranium. The *Technical Basis Document for the Fernald Environmental Management Project (FEMP) – Occupational External Dose* provides specific neutron factors to be used with photon exposures at FMPC. This particularly applies to the Pilot Plant, Plant 4, and associated warehouses.

### 5.3.4 Photon Exposures

When operational, FMPC was a large integrated facility that produced uranium metal products used as feed materials in DOE defense program facilities throughout the United States. FMPC utilized a number of processes that involved a variety of forms of uranium, including uranium ore concentrate, uranium hexafluoride, and recycled uranium scrap. The products were "variously sized, highly purified uranium metal forms of assorted standard isotopic assays" ranging from depleted to slightly enriched uranium metal products (ORAU-TKBS-17-06). The primary facilities, referred to as plants, are described in detail in *Technical Basis Document for the Fernald Environmental Management Project (FEMP) – Site Description*. The radiological hazards associated with these processes and products resulted from the radioactivity of uranium, thorium, and their daughter products, and in some instances, impurities in the recycled material.

Many activities took place during FMPC's period of operation. Throughput of material varied considerably, as did the sources of feed materials, one of which was ore from the Belgian Congo. That ore, pitchblende, contained large quantities of radium that required shielding. Wastes from this process were stored on the site in the K-65 silos. These silos also received waste from a site near Niagara Falls, New York. The silos became a large contributor to site background dose rates.

As seen in Table 5-5, the processing of thorium at FMPC resulted in a higher energy photon mix than that resulting from uranium decay chains alone. Pitchblende processing also resulted in a high-energy gamma component in the K-65 silos.

Table 5-5 summarizes default photon energies for FMPC materials.

**Table 5-5: Default Photon Energies for FMPC Materials**

| Energy | Thorium | Enriched Uranium | Depleted Uranium | Radium and Decay Chain |
|---|---|---|---|---|
| <30 keV | 0% | 0% | 0% | 0% |
| 30-250 keV | 16% | 100% | 50% | 0% |
| >250 keV | 84% | 0% | 50% | 100% |

### 5.3.5 Incidents and Fires

A review of FMPC operating history revealed that a number of fires and small explosions resulted from working with uranium and thorium metal, especially when molten metal, stored un-oxidized metal turning or scraps, or phosphorus and magnesium compounds were involved. Interviews with former FMPC workers, including fork truck operators tasked with moving burning drums of uranium, reinforced that small fires and explosions occurred frequently, perhaps even daily at times. The majority of these incidents resulted in only local contamination. Other incidents mentioned by interviewees included ventilation exhaust system filter bag breaches, high dust levels from certain operations, and spills from drums of uranium ore.

There were two serious incidents that had the potential to result in significant personnel exposure: a thorium blender incident and a uranium hexafluoride gas release.

#### 5.3.5.1 Thorium Blender Incident

On March 15, 1954, operators were attempting to blend a batch of thorium fluoride, calcium metal, and zinc chloride as a preparatory step to making thorium metal. During the process, which had been delayed repeatedly, an explosion and fire occurred. The fire resulted in the death of two operators. Several other workers in the vicinity received minor burns either from the initial fire or from providing assistance to injured operators.

The explosion spread material over a large area of Plant 9. An analysis of the event found that over 50 pounds of thorium were unaccounted for. This material was most likely volatilized and could have resulted in significant airborne contamination of the event site (Noyes, 1954).

#### 5.3.5.2 Uranium Hexafluoride Gas Release

On February 16, 1966, a major release from a 10-ton cylinder of uranium hexafluoride occurred in the Pilot Plant as operators attempted to initiate the uranium hexafluoride-to-uranium fluoride reduction process. Based on NIOSH's investigation of the incident, it appears that the pigtail portion of the valve broke, causing an un-isolable break in the container. The operator attempting to open the cylinder was engulfed in a cloud of uranium hexafluoride. Emergency actions were initiated. After approximately one hour, when the pressure in the cylinder dropped to the point that it could be plugged, the release was controlled.

The operator engulfed in the uranium hexafluoride was hospitalized with pulmonary edema. He was released a few days later and returned to work on February 23, 1966. Other Pilot Plant personnel were given prophylactic oxygen inhalations and released to return to work (AEC, 1966).

# 6.0 Summary of Available Monitoring Data for the Proposed Class

Historically, the main purpose of the radiation monitoring programs at FMPC was to ensure that worker exposures to radiation were kept below the annual prescribed occupational exposure limits in effect at that time. The initial health and safety organization (the Industrial Hygiene and Radiation Division) at FMPC was organized and directed by an occupational medical physician and staffed primarily with industrial hygienists. Because of similar radiation safety issues associated with the facility's uranium processing, the FMPC staff worked with Y-12 plant staff in Oak Ridge, Tennessee, to optimize program design and execution.

FMPC's radiological monitoring program was in place at the beginning of FMPC operations (1951) and included internal and external monitoring of personnel, as well as workplace and environmental monitoring. Individual doses from personnel dosimeters, urine samples, and *in vivo* analyses are available. Air monitoring and radiological survey results were well documented (and are available) in numerous FMPC reports (see Section 4.0).

Similar to other DOE facilities, the percentage of the FMPC worker population included in the personnel monitoring programs varied over time. FMPC monitoring practices reflect a focus on monitoring those workers with the highest likelihood of exposure. Thus, the FMPC monitoring program coverage was especially comprehensive as evidenced by the review of the FMPC claims for dose reconstruction that have been logged in the NIOSH OCAS Claims Tracking System (NOCTS). This review (see Subsection 4.4) revealed that of the 690 individual claims in NOCTS, internal monitoring data are available for 91% of the claimants and external monitoring data are available for 93% of the claimants.

The primary repository of FMPC monitoring data is managed for DOE by their site management contractor (currently Fluor-Daniel). As at other DOE sites, monitoring results were documented via hard-copy radiation exposure records and in memoranda for the earlier time frame. In later years, monitoring results were recorded directly into databases. Some, though not all, of the earlier hard copy data has been entered into the "Health Information System" electronic database (known as HIS-20). Not-yet-entered hard copy monitoring data are maintained in a secure filing system. A summary of data contained within the HIS-20 database is presented in Table 6-1.

**Table 6-1: Summary of HIS-20 Monitoring Data (1952-1983)**

| | Urinalysis | | External Monitoring | |
|---|---|---|---|---|
| **Year** | **# of Records** | **# of Employees Monitored** | **# of Records** | **# of Employees Monitored** |
| 1952 | 288 | 72 | 1,158 | 1,154 |
| 1953 | 2,436 | 753 | 1,742 | 1,739 |
| 1954 | 8,724 | 1,392 | 2,438 | 2,437 |
| 1955 | 10,669 | 1,982 | 2,668 | 2,662 |
| 1956 | 11,314 | 2,514 | 2,890 | 2,883 |
| 1957 | 13,581 | 2,990 | 2,704 | 2,699 |
| 1958 | 9,992 | 2,542 | 2,373 | 2,366 |
| 1959 | 14,549 | 2,655 | 2,398 | 2,392 |
| 1960 | 19,386 | 2,709 | 2,438 | 2,433 |
| 1961 | 9,505 | 2,443 | 2,507 | 2,502 |
| 1962 | 8,486 | 2,191 | 2,206 | 2,201 |
| 1963 | 9,673 | 2,041 | 2,063 | 2,058 |
| 1964 | 6,748 | 1,919 | 1,979 | 1,977 |
| 1965 | 6,561 | 1,680 | 1,665 | 1,659 |
| 1966 | 6,379 | 1,660 | 1,636 | 1,634 |
| 1967 | 5,359 | 1,674 | 1,620 | 1,618 |
| 1968 | 4,607 | 1,423 | 1,542 | 1,540 |
| 1969 | 3,217 | 1,321 | 1,255 | 1,251 |
| 1970 | 3,081 | 1,126 | 972 | 972 |
| 1971 | 2,234 | 884 | 768 | 767 |
| 1972 | 2,207 | 686 | 555 | 553 |
| 1973 | 2,748 | 790 | 602 | 601 |

| Table 6-1: Summary of HIS-20 Monitoring Data (1952-1983) | | | | |
|---|---|---|---|---|
| | Urinalysis | | External Monitoring | |
| Year | # of Records | # of Employees Monitored | # of Records | # of Employees Monitored |
| 1974 | 2,508 | 712 | 579 | 576 |
| 1975 | 2,293 | 718 | 569 | 565 |
| 1976 | 2,045 | 709 | 541 | 528 |
| 1977 | 1,853 | 681 | 524 | 493 |
| 1978 | 1,666 | 655 | 500 | 464 |
| 1979 | 1,534 | 634 | 484 | 445 |
| 1980 | 1,566 | 652 | 515 | 459 |
| 1981 | 2,125 | 742 | 3,782 | 700 |
| 1982 | 2,095 | 266 | 5,306 | 914 |
| 1983 | 3,381 | 977 | 6,147 | 1,026 |

## 6.1 FMPC Internal Monitoring Data

The following information provides a general summary of the FMPC internal monitoring program, as well as the types, quantity, and quality of the resulting data that can be used for internal dose reconstruction. Details regarding the various analyses used and the associated minimum detectable activities are presented in *Technical Basis Document for the FMPC-Occupational Internal Dose* (ORAU-TKBS-0017-5).

A radiological control program was in place from the start of FMPC operations. The internal dose control sampling program consisted of the following:

- Routine air sampling was used in all plants and operational processing areas to evaluate internal exposure potential via inhalation and served as the primary means of controlling intakes. This sampling was performed over the entire operational period evaluated in this report, from the start of FMPC operations through 1989 (ORAUT-TKBS-0017-5).

- Urine samples were submitted after at least a two-day work break to allow elimination of uranium cleared rapidly via the GI tract (uranium that clears rapidly from the body causes relatively little dose). The FMPC urinalysis program began on or about the start of FMPC operations (1952-

1953) and continued over the remaining operational period evaluated in this report, through 1989 (ORAUT-TKBS-0017-5).

- Routine *in vivo* analysis was performed with the frequency of monitoring based on the individual's exposure potential and urine sampling results (more frequent for those workers working in high-exposure potential jobs). As indicated in the FMPC Internal TBD, lung counting became available at the FMPC in 1968 (in the form of the Mobile In Vivo Radiation Monitoring Laboratory) and continued over the remaining operational period evaluated in this report (ORAUT-TKBS-0017-5).

**Air Sampling Data**

Based on the large quantity of data archived in the form of data sheets, memos, reports, etc., it is clear that from the beginning of operations, FMPC maintained an aggressive air monitoring program. Routine air samples were taken in each plant and in each operational area. The air monitoring program was used as the primary means of controlling intakes (ORAUT-TKBS-0017-5).

In the 1950s, both high and (primarily) low-volume general area and breathing zone air samples were collected (most for 3 to 30 minutes.) and counted for alpha contamination. A few sample records and claim file records indicate that some beta counts were performed (ORAUT-TKBS-0017-5).

In the 1960s, the samples were counted for both alpha and beta activity. To determine action levels, the results were compared to the National Lead Concentration Guide (NCG) of 100 dpm $m^{-3}$ (70 dpm $m^{-3}$ was used as the MAC/NCG until the 1970s) (ORAUT-TKBS-0017-5).

In 1986, Westinghouse Material Company of Ohio implemented a continuous air sampling program in FMPC production areas (ORAUT-TKBS-0017-5).

Thorium air sampling was performed in areas of the FMPC where thorium was processed or stored. The Site Research Database (SRDB) contains limited air sampling data taken during thorium processing in Plant 1, Plant 2/3, Plant 6, Plant 8, Plant 9, the Pilot Plant, and the Developmental Machine Shop. A limited number of thorium samples were also found re-counted after a decay period to determine thoron levels. During the 1980s, a routine radon and thoron sampling program was established. Air monitoring data, specific to thorium operations, are being expanded through continuing historical data recovery efforts currently in progress for the technical basis document revision. New data, as discovered, will be added to the SRDB.

Extensive, long-term air activity summary sheets that cover 15 or more years are available. These summary sheets indicate routine detectable air activity in all working areas of each plant. In addition, these summaries detail annual average exposures to workers without respiratory protection and average air activities associated with job assignments that required respirators (ORAUT-TKBS-0017-5).

**Bioassay Sampling Data**

Starting in 1952, a urinalysis program was initiated at FMPC. The fundamental, primary bioassay during FMPC's first 35 years of operation was urine analysis for uranium, reported in milligrams per liter. Industrial physicians and industrial hygienists for National Lead of Ohio, Inc. performed and documented a number of studies to establish the uptake or maximum permissible body burden for workers exposed to uranium. Their initial study was based solely on heavy metal toxicological limits for kidney damage (ORAUT-TKBS-0017-5).

Nearly all employees provided urine samples for uranium analysis (via fluorophotometry) at the time of their annual physicals. Workers who had assignments that were more likely to result in exposure were sampled weekly, monthly, or (at least) bimonthly. As discussed previously, these data are stored in the HIS-20 database and are available through DOE (ORAUT-TKBS-0017-5).

Radionuclides other than uranium were analyzed on occasion throughout the years, predominantly by contract laboratories. During the early 1950s, several radon breath analyses were conducted for workers handling radium bearing materials. These data are important in demonstrating that workers that had the potential for exposure to radium bearing materials were in fact monitored. The breath radon data results for years 1952, 1953, and 1954 are available in the SRDB (SRDB Ref. IDs 3167, 3191, 3193, and 3197).

Fecal sampling has never been included in the routine bioassay program. However, since 1986, it has been recognized at FMPC that fecal sampling can provide useful information; fecal sampling has only been utilized at the site in special conditions. As a result, very little fecal sampling data applicable to the proposed class timeframe are available.

### *In Vivo* Analytical Data

Although two lung counts were performed in 1965, lung counting did not become widely available at FMPC until 1968. Lung counting was performed by the Mobile In Vivo Radiation Monitoring Laboratory (MIVRML). Table 6.2 shows the number of measurements reported in the MIVRML data from the FMPC. Each result has been entered into a spreadsheet and is being analyzed to determine annualized lognormal distribution parameters for each measurement type.

The mobile van visited FMPC routinely and performed lung counting based on worker internal exposure potential and worker urine sampling results. After lung counting became available, the annual reports to the Atomic Energy Commission listed the number of workers who exceeded 50% of the maximum permissible lung burden and the calculated annual doses to the lung in rem (ORAUT-TKBS-0017-5).

**Table 6.2: Number of *In Vivo* Measurements Performed Annually at the FMPC (as reported in MIVRML)**

| Year | Uranium-235 | Uranium | Thorium | Lead-212 | Actinium-228 |
|---|---|---|---|---|---|
| 1965 | 2 | 2 | 0 | 2 | 2 |
| 1968 | 306 | 362 | 310 | 2 | 1 |
| 1969 | 107 | 108 | 107 | 0 | 0 |
| 1970 | 168 | 168 | 164 | 0 | 0 |
| 1971 | 686 | 686 | 680 | 3 | 2 |
| 1972 | 277 | 277 | 274 | 1 | 0 |
| 1973 | 235 | 235 | 233 | 2 | 1 |

**Table 6.2: Number of *In Vivo* Measurements Performed Annually at the FMPC (as reported in MIVRML)**

| Year | Uranium-235 | Uranium | Thorium | Lead-212 | Actinium-228 |
|---|---|---|---|---|---|
| 1974 | 324 | 324 | 321 | 1 | 1 |
| 1975 | 277 | 277 | 275 | 0 | 0 |
| 1976 | 267 | 267 | 262 | 1 | 1 |
| 1977 | 219 | 218 | 217 | 3 | 3 |
| 1978 | 212 | 214 | 161 | 40 | 41 |
| 1979 | 216 | 224 | 26 | 198 | 197 |
| 1980 | 232 | 239 | 5 | 214 | 219 |
| 1981 | 171 | 176 | 3 | 166 | 170 |
| 1982 | 209 | 215 | 3 | 204 | 210 |
| 1983 | 212 | 217 | 4 | 195 | 200 |
| 1984 | 410 | 419 | 4 | 408 | 415 |
| 1985 | 426 | 418 | 3 | 405 | 407 |
| 1986 | 506 | 507 | 10 | 467 | 467 |
| 1987 | 577 | 576 | 12 | 570 | 566 |
| 1988 | 229 | 228 | 3 | 111 | 107 |
| 1989 | 6 | 6 | 0 | 1 | 1 |

Industrial Hygiene & Radiation Department Internal Deposition Action Level procedures dating from around 1970 suggest actions related to determining the percent maximum permissible lung burden of either uranium or thorium. Uranium-235 was detected primarily by emission of its 186 keV photon. Uranium-238 was calculated by measuring its thorium-234 progeny that was assumed to be in equilibrium with the uranium-238. Thorium-232 and thorium-228 activities were determined based on equilibrium assumptions and detection of their progeny (most likely actinium-228 for thorium-232, but lead-212 may have been used for assessment of both thorium isotopes). Thorium-230 is not readily detectable by *in vivo* measurements. There was apparently no attempt to detect transuranic contaminants using the Mobile In Vivo Radiation Monitoring Laboratory. In fact, the only determination made with the mobile van was to quantify the uranium lung burden in milligrams or micrograms of uranium, with the assumption of 1% enrichment and of occasional thorium lung burdens as indicated by some claim records.

The results from the Mobile In Vivo Radiation Monitoring Laboratory were calibrated in μCi of uranium-235 and reported in milligram of uranium in the lung, which was translated to maximum permissible lung burden based on the assumed enrichment (generally 1%). The workers who had known exposures to high air concentrations, had high urine results, or were involved in an incident, were counted as the first priority each time the Mobile In Vivo Radiation Monitoring Laboratory visited the site. Other workers were counted based upon their job exposure potentials, as shown in Table 6-3.

**Table 6-3 Typical MIVRML[1] Counting Schedule at the FMPC in the 1970s**

| **Labor Category Description** | ***In Vivo* Counting Schedule** |
|---|---|
| All Chemical Operators | Once per year |
| Members of Project Labor Pool | |
| Mechanical Department Crafts | During each MIVRML visit, 25% of the employees in these classifications were scheduled to be counted, and each worker would be counted at least once during a 2-year period. |
| Mechanical Department Laborer | |
| Laundry Group | |
| Industrial Truck Operator | |
| Locomotive Operator | |
| Switchman | |
| Graphite Shop Machinist | |
| Machine Tool Operator | |
| Degreaser | |
| Crane Operator | |
| Stamper | |
| Plant 6 Laborer | |
| Furnace Operator Heater | |
| Mill Man | |
| Decontaminator | |
| Transportation Laborer | |
| Cafeteria | Salaried personnel and workers in these classifications were not routinely counted because of low chronic exposure and low potential for unobserved acute exposures. |
| Water Treatment Group | |
| Power Plant Group | |
| Heavy Equipment Operator | |
| Motor vehicle Operator | |
| Stores Warehouse Attendant | |
| Checker | |
| Industrial Mechanic | |
| Security Police Officer Porter | |
| Toolmaker | |
| Machine Set-up | |
| Tool Room Machinist | |
| Gauge Set-up | |
| Inspector | |

**Note:**
[1] **Mobile In Vivo Radiation Monitoring Laboratory**

## 6.2 FMPC External Monitoring Data

The following information provides a general summary of the FMPC external monitoring program, as well as the types, quantity, and quality of the data that can be used for external dose reconstruction. Details regarding the various analyses used, the associated minimum detectable activities, the calibration procedures used, and details regarding missed doses are available in *Technical Basis Document for the FMPC-Occupational External Dose* (ORAUT-TKBS-0017-6).

FMPC production workers have always used dosimeters, and as described in Section 6.0, these data are available. Table 6-4 shows the periods when male employees and female employees were and/or were not monitored.

**Table 6-4: FMPC Monitoring of Employees by Gender**

| Timeframe | Males Monitored | Females Monitored |
|---|---|---|
| **1951-1960** | YES | NO |
| **1961-1968** | YES | YES |
| **1969-1978** | YES | NO |
| **1979-Present** | YES | YES |

*A Response to Dosimetry Assessment Fact Sheet* states that female employees were not monitored during certain periods because the potential did not exist for them to exceed 10% of the quarterly standards since they were not production workers (Dugan 1981).

FMPC used several types of personnel dosimeters throughout its operational period. There were also several changes in occupational and administrative exposure limits during that period, including dosimeter exchange periods. Table 6-5 summarizes information regarding the dosimeters and filters that were used, as well as the exchange frequencies.

**Table 6-5: FMPC Dosimeter Characteristics**

| Years | Dosimeter | Filters | Exchange Frequency |
|---|---|---|---|
| 1951-1954 | Two-element film | Open, Cadmium 1mm | Weekly |
| 1954-1958 | ORNL dosimeter | Open, Copper, Cadmium, Plastic, Lead | Biweekly |
| 1959-1985 | ORNL dosimeter | Open, Copper, Cadmium, Plastic, Lead | Monthly |
| 1985-1989 | Commercial Panasonic TLD | Multiple | Monthly |

FMPC dosimetry technology was approximately equivalent to that used throughout the nuclear industry at the time. FMPC followed the Oak Ridge National Laboratory program for dosimeter design and calibration. The exception was FMPC's lack of a requirement for neutron dosimetry.

At the time of facility startup in 1951, occupational whole-body doses were controlled to 0.3 R/week and an extremity dose of 1.5 R/week. The annual limit for maximum whole-body dose for any one-year period was 12 rem, and the annual extremity limit was 75 rem; both values had associated administrative limits that were fractions of the annual limits per calendar quarter. In 1955, the whole-body dose limits were reduced to 3 rem per 13 weeks, not to exceed 5 rem per year. It should be noted that the terms roentgen, rad, rem, and rep (roentgen-equivalent physical) often are used interchangeably, and this document makes the claimant-favorable assumption that they are considered equal.

Since FMPC operation began in 1951, various radiation dose concepts and quantities have been used to measure and record occupational dose. A basis of comparison for dose reconstruction is the concept of Personal Dose Equivalent, Hp(d), where d identifies the depth (in mm) and represents the point of reference for dose in tissue. For penetrating radiation of significance to whole body dose (e.g. high-energy photons), d = 10 mm and is noted as Hp(10). For weakly penetrating radiation of significance to skin dose, d = 0.07 mm, and is noted as Hs(0.07).

Extremity dosimetry at the FMPC involved the use of wrist dosimeters (rather than finger dosimeters) and the application of an appropriate correction factor. Early worker exposure records indicate that a factor of three was likely used as the correction factor (ORAUT-TKBS-0017-6). Documentation of the correction factor was not established until a study referenced in *Technical Basis Document for the Fernald Environmental Management Project (FEMP) – Occupational External Dose* determined that a factor of 2.06 times the wrist dosimeter value should be used to estimate the dose to the extremity (ORAUT-TKBS-0017-6). At the time of the study referenced in *Technical Basis Document for the Fernald Environmental Management Project (FEMP) – Occupational External Dose,* the wrist dosimeter being used was a Teflon disk embedded with CaSO4: Dy. However, records indicate that film had previously been used at FMPC.

While using wrist-to-finger ratios to estimate extremity doses is not a particularly accurate practice, this approach was used at many DOE sites, with each site determining its own correction factor. Since the wrist dosimeter is worn on the outside of clothing and may be shielded by protective clothing on the extremities (e.g. gloves), using the wrist-to-finger ratios could over estimate dose by as much as 20%. Therefore, the recorded extremity doses should be claimant favorable and provide the best estimate of Hs(0.07) for individual monitored employees.

Individual exposure records suggest an "open window" design for personnel monitoring devices that allowed both beta and photon radiation to reach the measuring element (film or thermoluminescent dosimeter (TLD)). Some DOE sites incorporated a security badge in the dosimeter holder that in some instances covered the open window of the dosimeter. However, FMPC did not cover the open window with its security credential (Dugan 1981), thus providing more accurate results than if the window had been covered.

There were several instances throughout FMPC when workers were subjected to high levels of radioactive material-bearing dust. This widespread source of contamination was a concern for proper use of personal dosimeters, and as a result, the dosimeters were enclosed in plastic bags to protect against dust contamination. The manner in which these contaminated dosimeters were handled was not identified. However, this should not inhibit dose reconstruction because the dosimeters were calibrated in plastic bags and no adjustments were made to the dosimeter results for either Hs(0.07) or Hp(10) (ORAUT-TKBS-0017-6).

Because Hp(10) may be of predominant interest in dose reconstruction, uranium beta radiation can be considered insignificant. An evaluation of original recorded doses for FMPC workers based on these parameters should yield a good (best available) estimate of Hp(10). Where necessary, Hs (0.07) for those individual workers who came in direct contact with radiological source materials can also be obtained because open window results were recorded with no adjustments to those readings.

# 7.0 Feasibility of Dose Reconstruction for the Proposed Class

The feasibility determination for the proposed class of employees covered by this evaluation report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(1). Under this Act and rule, NIOSH must establish whether it has access to sufficient information either to estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class, or to estimate the radiation doses to members of the class more precisely than a maximum dose estimate. If NIOSH has access to sufficient information for either case, NIOSH would then determine that it was feasible to conduct dose reconstructions.

In determining feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class (identified in Section 9.0 of this report). If not, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might allow NIOSH to estimate either the maximum doses that members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class (summarized in Section 7.6). This approach is discussed in OCAS's SEC Petition Evaluation Internal Procedures (OCAS-PR-004) available at http://www.cdc.gov/niosh/ocas. The next four major subsections of this Evaluation Report examine:

- the sufficiency and reliability of the available data - (Section 7.1)
- the feasibility of reconstructing internal radiation doses - (Section 7.2)
- the feasibility of reconstructing external radiation doses - (Section 7.3)
- the bases for petition SEC-00046 as submitted by the petitioner - (Section 7.4)

## 7.1 Pedigree of FMPC Data

Examination of the primary internal and external monitoring data available for FMPC employees indicates that those data are of sufficient quality and quantity and adequately represent the range of exposures associated with the work performed over the years identified in this evaluation. As discussed in detail in the FEMP Internal and External Technical Basis Documents, the monitoring approaches (targeting potential high-exposure work areas) and analytical techniques used to assess worker exposures at FMPC were commensurate with the state-of-the-art programs used at other DOE facilities (ORAUT-TKBS-0017-5 and ORAUT-TKBS-0017-6).

Though data for specific non-uranium radionuclides are not as readily available, uranium has always been the dominant contributor to collective internal and external doses at FMPC. Generally small in comparison, doses from other radionuclides known to be present can be capped with the use of available gross alpha and beta results, use of conservative ratio assumptions, and the use of air sampling results which are available for every plant and operational area (see subsection 7.2).

### 7.1.1 Internal Data Review

Consistency of available internal monitoring data was checked by reviewing *in vitro* and *in vivo* analytical results. Based on conversations with FMPC data management personnel, essentially all of the uranium urinalysis laboratory results have been entered into the HIS-20 Database. As a result, most hard copy laboratory results have been placed in storage at the Dayton, Ohio Federal Records Center. However, some records from the mid to late 1950s are still present at FMPC and copies of these records are being supplied for inclusion into FMPC EEOICPA claimant files. Comparisons between analytical laboratory results available in four claimant files and those entered into the HIS-20 Database were checked for internal data consistency. The results are presented in Table 7-1 as they appear in their respective sources (units, significant digits) (NLC, 1972; NLC, 1975; and Scudder, 1971).

**Table 7-1: Uranium Urinalysis Data Comparison**

| Employee | Analytical Laboratory – Health and Safety Division Results | | HIS-20 Records | |
|---|---|---|---|---|
| | Date | Result (mg/l) | Date | Result (µgU/l) |
| Employee 1 | 12-14-1956 | 0.015 | 12-14-1956 | 15.00 |
| | 12-17-1956 | 0.021 | 12-17-1956 | 21.00 |
| | 03-11-1957 | 0.007 | 03-11-1957 | 7.00 |
| | 02-12-1958 | 0.010 | 02-12-1958 | 10.00 |
| | 04-30-1958 | 0.007 | 04-30-1958 | 7.00 |
| Employee 2 | 03-13-1956 | 0.020 | 03-13-1956 | 20.00 |
| | 07-01-1957 | 0.021 | 07-01-1957 | 21.00 |
| | 07-19-1957 | 0.005 | 07-19-1957 | 5.00 |
| Employee 3 | 09-08-1955 | 0.068 | 09-08-1955 | 68.00 |
| | 12-29-1955 | 0.052 | 12-29-1955 | 52.00 |
| | 12-29-1955[1] | 0.008 | 12-29-1955[1] | 8.00 |
| | 02-20-1956 | 0.238 | 02-20-1956 | 238.00 |
| | 03-12-1956 | 0.066 | 03-12-1956 | 66.000 |
| | 06-29-1956 | 0.047 | 06-29-1956 | 47.00 |
| | 07-02-1956 | 0.035 | 07-02-1956 | 35.00 |
| | 08-07-1956 | 1.100 | 08-07-1956 | 1100.00 |
| | 08-08-1956 | 0.088 | 08-08-1956 | 88.00 |
| | 08-09-1956 | 0.032 | 08-09-1956 | 32.00 |
| | 08-10-1956 | 0.117 | 08-10-1956 | 117.00 |

**Table 7-1: Uranium Urinalysis Data Comparison**

| Employee | Analytical Laboratory – Health and Safety Division Results | | HIS-20 Records | |
|---|---|---|---|---|
| | Date | Result (mg/l) | Date | Result (µgU/l) |
| | 10-10-1956 | 0.060 | 10-10-1956 | 60.00 |
| | 10-11-1956 | 0.017 | 10-11-1956 | 17.00 |
| | 10-16-1956 | 0.040 | 10-16-1956 | 40.00 |
| | 10-30-1956 | 0.030 | 10-30-1956 | 30.00 |
| | 10-31-1956 | 0.003 | 10-31-1956 | 2.00 |
| | 11-01-1956 | 0.006 | 11-01-1956 | 6.00 |
| | 11-03-1956 | 0.067 | 11-03-1956 | 67.00 |
| | 11-04-1956 | 0.086 | 11-04-1956 | 86.00 |
| | 05-17-1957 | 0.065 | 05-17-1957 | 65.00 |
| | 07-01-1957 | 0.028 | 07-01-1957 | 28.00 |
| Employee 4 | 10-11-1955 | 0.022 | 10-11-1955 | 22.00 |
| | 03-11-1957 | 0.019 | 03-11-1957 | 19.00 |
| | 02-03-1958 | 0.075 | 02-03-1958 | 75.00 |
| | 03-20-1958 | 0.024 | 03-20-1958 | 24.00 |

**Source for Comparison: NLC, 1972; NLC, 1975; and Scudder, 1971**
**Note:**
**[1] Second reading on 12-29-55**

As can be seen in the Table 7-1, there was only a single minor discrepancy (0.002 verses 0.003 mg/l result for Employee 3, 10-31-1956) between hardcopy analytical results and those results that are stored in the HIS-20 Database.

*In vivo* data for FMPC employees are available and original hardcopy files serve as the source of this information. Because these data are still in original hardcopy (and handwritten) form, no consistency checks are applicable.

### 7.1.2 External Data Review

Information found in FMPC claimant files was used to check reporting consistency for external monitoring data. The same four files that were used for the internal data check were also used for the external monitoring check. Initially, external readings were read and recorded weekly; but during the 39th week of 1956, the exchange and read frequency changed from weekly to bi-weekly. Beginning in 1959, external readings and recordings occurred on a monthly basis. Regardless of the exchange frequency, handwritten records were maintained for each monitored employee and for each badge reading. In addition, a summary radiation exposure record card, which presents annual and cumulative exposures measured, was maintained in each employee file. For comparison purposes of this evaluation, the available weekly and monthly monitoring results were compiled into annual doses so that the external doses could be easily compared to the summary radiation exposure record cards.

Table 7-2 presents the results of an external monitoring data comparison performed between the two types of employee exposure record cards and the HIS-20 Database. As completed for the internal comparison, the data are shown and displayed as they occurred in their original sources with regards to units and significant figures. Aside from some apparent rounding when recording on the annual and cumulative exposure record cards, the data sets agree (NLC, 1972; NLC, 1975; and Scudder, 1971).

**Table 7-2: External Data Comparison: FMPC**

| Employee | Year | Annual Totals Compiled from Weekly/Biweekly Exposure Records[1] (mr) | | Results from Annual Summary Exposure Records[1] (R) | | HIS – 20 Database Values[2] Annual Totals (rem) | |
|---|---|---|---|---|---|---|---|
| | | β | γ | γ | β + γ | DDE[3] | SDE,S[4] |
| Employee 1 | 1956 | 500 | 0 | 0 | 0.5 | 0.000 | 0.500 |
| | 1957 | 0 | 0 | 0 | 0 | 0.000 | 0.000 |
| | 1959 | - | - | 0 | 0.1 | 0.000 | 0.100 |
| | 1964 | - | - | 0 | 0.1 | 0.000 | 0.059 |
| | 1967 | - | - | 0 | 0.2 | 0.000 | 0.181 |
| | 1975 | - | - | 1.0 | 13.4 | 1.023 | 13.395 |
| | 1986 | - | - | 0 | 0.1 | 0.000 | 0.084 |
| Employee 2 | 1953 | 295 | 515 | 0.5 | 0.8 | 515 | 0.810 |
| | 1955 | 670 | 1170 | 1.2 | 1.8 | 1.17 | 1.84 |
| | 1959 | - | - | 0.3 | 1.5 | 0.028 | 1.547 |
| | 1962 | - | - | 0.6 | 2.8 | 0.565 | 2.815 |
| | 1966 | - | - | 1.2 | 6.7 | 1.214 | 6.729 |
| | 1974 | - | - | 1.4 | 3.2 | 1.409 | 3.238 |
| Employee 3 | 1953 | 3,055 | 35 | 0 | 3.1 | 0.035 | 3.09 |
| | 1954 | 6,175 | 1,910 | 1.7 | 7.9 | 1.91 | 8.085 |
| | 1965 | - | - | 3.2 | 10.7 | 3.247 | 10.717 |
| | 1971 | - | - | 0.3 | 13.2 | 0.26 | 13.169 |
| | 1983 | - | - | 0.4 | 9.0 | 0.408 | 9.017 |
| Employee 4 | 1954 | 425 | 40 | 0 | 0.5 | 0.000 | 0.465 |
| | 1956 | 920 | 0 | 0 | 1.0 | 0 | 0.97 |
| | 1959 | - | - | 0 | 1.8 | 0.020 | 1.835 |
| | 1969 | - | - | 0.3 | 2.0 | 0.290 | 1.955 |
| | 1972 | - | - | 0.8 | 13.6 | 0.845 | 13.612 |
| | 1982 | - | - | 0.4 | 1.4 | 0.384 | 1.372 |

**Source for Comparison: NLC, 1972; NLC, 1975; and Scudder, 1971**
**Notes:**
**- Cards dated 1957 and earlier are currently still stored at FMPC and readily available for comparison as they have been supplied by FMPC for inclusion into individual claimant NOCTS files. Cards dating from 1958 and later have been shipped off by FMPC to be stored at the Dayton, Ohio Federal Records Center. At this time, data on the 1958 and later cards have not been included in this comparison.**
**[1] Results are from handwritten film badge exposure record cards that were filed for each monitored worker by the FMPC Analytical Department, Health and Safety Division.**
**[2] Like the original exposure record cards, database values are recorded per week prior to the 39th week of 1956, bi-weekly from that point through the end of 1958, and then monthly from that point on.**
**[3] Deep Dose Equivalent (γ)**
**[4] Shallow Dose Equivalent, Skin (β + γ)**

An additional data consistency comparison was performed between data contained within the HIS-20 Database and results recorded for individuals in several interoffice memoranda from the early to mid

1970s. Table 7-3 presents the results of this comparison (NLC, 1972; NLC, 1975; and Scudder, 1971).

| **Table 7-3: Comparison of Exposures Between Internal Correspondence and HIS-20 Database** | | | | | |
|---|---|---|---|---|---|
| **Employee** | **Badge Period Reported in Memos** | **Monthly Dose Reported in Memo (mrem)** | | **HIS – 20 Database Monthly Dose Values[1] (rem)** | |
| | | **β + γ** | **γ** | **DDE[2]** | **SDE, S[3]** |
| Employee 1 | 01-06-1971 to 02-03-1971 | 1,325 | 19 | 0.019 | 1.310 |
| | 02-03-1971 to 03-03-1971 | 1,543 | 38 | 0.038 | 1.543 |
| | 03-03-1971 to 04-07-1971 | 1,959 | 73 | 0.072 | 1.958 |
| | 04-07-1971 to 05-05-1971 | 1,550 | 37 | 0.037 | 1.483 |
| Employee 2 | 05-03-1972 to 05-31-1972 | 1,870 | 63 | 0.062 | 1.870 |
| | 05-31-1972 to 06-28-1972 | 1,625 | 73 | 0.073 | 1.626 |
| | 09-06-1972 to 10-04-1972 | 1,610 | 140 | 0.140 | 1.624 |
| | 10-04-1972 to 11-01-1972 | 1,390 | 139 | 0.137 | 1.391 |
| Employee 3 | 02-05-1975 to 03-05-1975 | 1,300 | 120 | 0.120 | 1.328 |
| | 03-05-1975 to 04-02-1975 | 1,800 | 135 | 0.134 | 1.819 |
| | 04-02-1975 to 04-30-1975 | 1,425 | 111 | 0.111 | 1.447 |
| | 08-06-1975 to 09-03-1975 | 1,331 | 118 | 0.118 | 1.331 |
| Employee 4 | 01-01-1975 to 02-05-1975 | 540 | 275 | 0.276 | 0.536 |
| | 03-05-1975 to 04-02-1975 | 430 | 225 | 0.228 | 0.431 |
| | 04-30-1975 to 05-28-1975 | 520 | 270 | 0.266 | 0.519 |
| | 08-06-1975 to 09-03-1975[4] | 630 | 330 | 0.029 | 0.078 |

**Source for Comparison: NLC, 1972; NLC, 1975; and Scudder, 1971**

**Notes:**

**[1] Like the original exposure record cards, database values are recorded per week prior to the 39th week of 1956, bi-weekly from that point through the end of 1958, and then monthly from that point on.**

**[2] Deep Dose Equivalent (γ)**

**[3] Shallow Dose Equivalent, Skin (β + γ)**

**[4] Remarks in memo noted "dark spots, possible contamination". NIOSH has not obtained information regarding how the final dose recorded in the database was determined.**

## 7.2 Internal Radiation Doses at FMPC

The principal source of internal radiation doses for members of the proposed class was airborne uranium particulate material. This dust could be inhaled by individuals and then deposited in the respiratory tract. The dust would also settle on surfaces and become re-suspended in the air where it could again be inhaled or ingested by transfer from contaminated surfaces via hand to mouth. The majority of the exposures over the history of FMPC operations are considered to be chronic in nature.

The bioassay program was established at the start of production. Bioassay results are available from the start of operations in 1952.

In addition to uranium, which is the primary radionuclide contributing to internal dose at FMPC; exposure to various other radionuclides could have occurred. The other radionuclides of concern include thorium and the associated decay products, uranium decay products (including radium and the associated decay products), fission/activation products, and transuranics (recycled uranium contaminants).

The subsections below summarize the extent and limitations of information available for reconstructing the internal doses of members of the class. Most of the information summarized below is provided in greater detail in the individual TBDs and other document sources as described in Section 4.0.

### 7.2.1 Process-Related Internal Doses at FMPC

The following subsections summarize the extent and limitations of information available for reconstructing the process-related internal doses of members of the proposed class.

#### 7.2.1.1 Urinalysis Information and Available Data

NIOSH has access to thousands of urinalysis results representing the majority of the FMPC worker population at different times during the period covered by this report. FMPC began *in vitro* urinalysis using fluorophotometry in 1952. The practice at the facility was to collect a urine sample for uranium analysis from all employees at the time of the annual physicals, supplemented by frequent bioassay sampling of workers whose jobs required handling of uranium materials in the plant facilities.

The primary purpose of this initial program, in conjunction with medical examinations, was to monitor for nephrotoxicity from uranium. However, workers in uranium production areas were also included in the urinalysis program to estimate internal dose, which was reported in percent and/or fraction of the maximum permissible body burden/maximum permissible lung burden. The monitoring frequency for employees ranged from a weekly to an annual basis. Nearly all employees provided urine samples for uranium analysis at the time of their annual physicals. Workers who had work assignments where exposure could be expected on a routine basis were sampled weekly, monthly, or at least bimonthly.

Only a few thorium *in vitro* bioassay results were identified during NIOSH's review for the time period evaluated in this report. Thorium was processed during 21 of the 35 year operational history of the FMPC (1954, 1955, 1960 to 1963, and 1964 to 1979). From 1968 to 1989, the Mobile In Vivo Measurement Laboratory from Y-12 provided lung count capabilities for thorium lung deposition. In the absence of specific bioassay data, thorium intakes are assigned on the basis of conservative assumptions and calculations based on measured air monitoring results.

Exposures to uranium daughter products during the processing and/or handling of raffinates from chemical processing of uranium ores were derived through calculations based upon air monitoring data and isotopic constituents derived from silo waste sampling.

Trace levels of contaminant radionuclides associated with recycled uranium work are also accounted for through application of a conservative ratio to uranium. The uranium urinalysis results used for dose reconstruction of uranium intake are used to obtain intakes of the recycled uranium contaminants through application of the analytical ratio. This default analysis is necessary, since bioassay for these isotopes were not available during the early years of operation. The associated methods are provided in *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational Internal Dose* (ORAUT-TKBS-0017-5).

Uranium compounds—in low enriched, depleted, and natural isotopic abundances— exhibiting all solubility types would have been present in various operations at FMPC during the site's history (ORAUT-TKBS-0017-5). Therefore, types F, M, and S are considered in the dose reconstruction process and applied in a manner that is favorable to the claimant.

#### 7.2.1.2 Analysis of Coworker Bioassay Data

Since nearly all FMPC workers were monitored for uranium in urine, no co-worker analysis has been deemed necessary for uranium intakes. However, there is an exception in the case of thorium dose reconstruction for workers exposed to thorium during the 1954 through 1955 and 1964 through 1968 time periods (prior to *in vivo* lung counting technology introduction). By using the lung counting database from 1968 through 1979 with the associated air monitoring data during the same times (which are being expanded at the present time for further historical data recovery efforts), the air monitoring data in the 1954 through 1955 and 1964 through 1968 period will be used to bound the exposures during those periods in which no bioassay analyses are available for thorium.

#### 7.2.1.3 Other Types of Bioassay/Workplace Indicators

As previously stated, the fundamental and primary bioassay for the first 35 years (1951 through 1986) of FMPC operational experience was urine analysis for uranium metal, reported in milligrams per liter. Radionuclides other than uranium have been analyzed on occasion through the years, predominantly by contract laboratories. Radon breath analyses taken in the early 1950s are available to bound occupational environmental exposures to FMPC workers from this source. The primary contract laboratory for FMPC *in vitro* analyses during the facility's early years of operation was United States Testing Company in Richland, Washington.

#### 7.2.1.4 Airborne Levels

NIOSH reviewed available process information for the entire operational period of the proposed class. Air monitoring programs were in place during this entire time period. These programs covered all operational areas and emphasized sample collection in process areas with higher potential for airborne contamination. In addition to general area airborne concentration levels, there are data available from job-specific breathing zone air sampling events. The number of available air sample results number in the thousands. Using process data, air sampling and bioassay results, and an assumed isotopic uranium source term (i.e., natural, enriched, and depleted uranium) when enrichment level is not recorded on the sample result, NIOSH can establish a maximum exposure scenario. Air monitoring data specific to thorium operations are currently being expanded through continuing historical data recovery efforts. The documented results, coupled with the recently recovered thorium lung count data, allow a default value to be established based on maximum credible assumptions.

#### 7.2.1.5 Other Radionuclides

Uranium has always been the dominant contributor to collective internal dose at FMPC. However, during 21 years of the total operational period, thorium was processed in quantities totaling approximately 0.3% of the quantities of uranium processed. Air monitoring specifically identified for thorium operations, coupled with an extensive lung count database during 11 years of that period, provides a basis for default intakes for workers who worked with these materials during the recorded periods of operation.

Monitoring for other radionuclides has been performed on a limited basis. Both the relatively small concentrations and the difficulty of analyses contributed to the lack of documented data. From 1961 until cessation of operations, a primary source of significant contaminants (including the production of other-than-normal uranium isotopes) that were introduced into FMPC plant systems were those associated with recycled uranium. Recycled uranium contained trace amounts of fission and activation products from reactor operations.

The predominant recycled uranium and associated contaminants (plutonium, neptunium, and technetium) came from other DOE facilities, which had also either generated and/or received recycled uranium materials. Therefore, nearly all of the uranium in the DOE facilities contained recycled uranium contaminants to varying degrees (through being processed by the same equipment, blending with other materials to adjust the degree of enrichment, etc.). Of special note is a uranium recovery effort of tower ash, which had significantly elevated transuranic contaminant levels, from the Paducah Gaseous Diffusion Plant. This material was blended and processed with existing uranium inventories, basically doubling the calculated inventories of these contaminants in the FMPC facilities for a period of time.

The fundamental conclusion in a variety of reports is that for dose reconstruction purposes, a conservative but reasonable default level of recycled uranium contaminants can be derived and applied as a percentage of the derived uranium intake for each of the four major contaminants. Analytical process information derived from a variety of sources allows calculation or interpolation of the levels of the predominant recycled uranium contaminants in the uranium materials received, processed, and handled at FMPC. Details regarding these calculations are contained in *Technical Basis Document for the FMPC Occupational Internal Dose* TBD (ORAUT-TKBS-0017-5).

A short-term exposure potential occurred during the July 1952 to September 1958 handling and transfer of raffinates from Mallinckrodt Chemical Works to K-65 storage silos. Approximately 13,000 55-gallon drums of raffinates were manually transferred to the silos. The isotopic inventories in the silos contained high percentage levels of radium-226. The attendant gaseous radon-222 decay product (and its associated progeny) produced a source of occupational exposure due to its emanation from the silos. Short term exposures to a few workers were possible during raffinate transfer operations during the 1950 time period. Few bioassay samples for radium were taken directly, although radon breath samples were taken during the early time period. Little radium intake is anticipated, although the breath samples will be used in conjunction with recorded air monitoring data to bound the worker intakes from this isotope.

A potential for exposure to thoron (radon-220) and its progeny occurred in areas where thorium was processed or stored. Although limited thoron sampling was found in the Pilot Plant (samples found for the years of 1965, 1968, and 1977), Building 65 (samples found for the year of 1965), and the Developmental Machine Shop (samples found for the year of 1954), quarterly thoron sampling in occupied areas at the FMPC became routine starting in the mid 1980s (Weaver 1987; Weaver May, 1987). By 1989, five “Working Level Monitors” were installed in areas where radon and thoron daughters were a concern, and thoron monitoring was performed upon entry into the thorium storage buildings, including Buildings 64, 65, and 68 (Walker, 1989).

Entry into the thorium storage areas, such as Building 64, 65, and 68, represent the worst case scenario at FMPC for thoron exposure since approximately 421 metric tons of thorium compounds (of the approximately 1,100 metric tons stored at the FMPC) were stored within these buildings. This represents a thorium quantity greater than that stored in any one area during the processing years (Parsons, 1993 Table 8-2; Dolan, 1988 Table 6; Mead 1985; Aas, 1986). Additionally, the thorium stored in these buildings was aged and would have been in an equilibrium condition with the thoron parent radionuclide radium-224. Many of the storage drums were also in a deteriorated condition (Parsons, 1993). Thus, the air samples taken upon entry into these thorium storage areas, or taken to monitor thorium repacking operations in 1989 and later, can be used to bound earlier exposures.

### 7.2.2 Ambient Environmental Internal Radiation Doses at FMPC

An evaluation of the ambient environmental internal radiation doses from plant releases of particulates/aerosols of uranium and the associated recycled uranium contaminants and thorium is not necessary because nearly all plant employees were monitored by routine air sampling and bioassay sampling. Thus, these doses are accounted for in the process-related internal dose evaluations.

Ambient environmental internal radiation exposure at the FMPC could have occurred from radon and its progeny, emanating from several radium bearing material storage areas (the K-65 silos, Plant 1 storage pad, and elevated Q-11 storage silos), and from thoron and its progeny, emanating from specific thorium production areas.

Radon (and daughter) emissions from various storage areas have been studied—*Condensed Final Report for Radon and Cigarette Smoking Exposure Assessment of Fernald Workers*, *The Fernald Dosimetry Reconstruction Project, Tasks 2 and 3*, *The Fernald Dosimetry Reconstruction Project, Task 6*, and *Uncertainty Analysis of Exposure to Radon Released from the Former Feed Materials Production Center*— and information available from within these reports, in addition to recently retrieved radon breath analyses, can be utilized to bound occupational environmental exposures to FMPC workers from this source (Killough, Pinney, RAC 1995, and RAC 1998). The report written by Susan Pinney provides bounding exposure information for cases where no data are available for use (Pinney, 2004).

As stated in the FMPC Environmental Monitoring Report for 1985, thoron (and daughter) emissions were monitored on a routine basis beginning in 1985 (Aas, 1986). In fact, 1985 was the first year that results from all isotopes of radon, including thoron (radon-220), were reported instead of just radon-222. Because the inventory of thorium (the source of thoron emanation) that was being stored at the FMPC was the greatest during the mid to late 1980s, the results from the mid to late 1980s can be used to bound environmental exposures from thoron.

### 7.2.3 Internal Dose Reconstruction Feasibility Conclusion

NIOSH has established that it has access to sufficient internal dose information to either: (1) estimate the maximum internal radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the internal radiation doses to members of the class more precisely than a maximum dose estimate.

Recorded bioassay for uranium is extensive and sufficient for internal dose reconstruction. Thorium bioassay is not as well documented. However, with the addition of a database of *in vivo* bioassay (lung counting) and additional air sampling data currently being expanded, the air monitoring database is being strengthened through recent retrieval of additional field data, which will be used to ensure a claimant favorable dose reconstruction to represent maximum dose.

Other radioisotopes were either: (1) contaminants present in recycled uranium, which may be accounted for adequately in dose reconstruction by applying conservative radionuclide ratios, or (2) specific isotopes of uranium and thorium progeny that resulted in short exposure duration to a limited number of workers. These possible intakes will be reconstructed by using air monitoring data and K-65 silo isotopic inventories.

The specific additional dose resulting from radon effluent from the K-65 silo can also be bounded by theoretical diffusion calculations.

## 7.3 External Radiation Doses at FMPC

The processes that generated the principal sources of external radiation dose are described in Section 5 of this document. As documented in the *Technical Basis Document for the Fernald Environmental Management Project – Occupational External Dose*, the principal sources of external radiation included uranium and thorium compounds or metals and their radioactive progeny, especially the high energy beta emitter protactinium-$234^{m}$ and the gamma emitter radium-226. Beginning in 1961, recycled uranium brought trace levels of transuranics and other radionuclides into the facility. Low energy beta radiation from technetium-99, which is a fission product present in recycled uranium, is measured by the dosimeter as non-penetrating radiation. Neutron dose may have resulted from work around uranium compounds that included fluorine atoms, specifically green salts (uranium fluoride) and uranium hexafluoride. These fluorination materials were present in the Pilot Plant and Plant 4, as well as the Warehouse and Storage areas.

### 7.3.1 Process-Related External Radiation Doses at FMPC

The following subsections summarize the extent and limitations of information available for reconstructing the process-related external doses of members of the proposed class.

#### 7.3.1.1 Radiation Exposure Environment

The external dose received by workers at FMPC was a function of the physical location of the workers on the site, the process taking place, the type and quantities of material present, and the time spent in each location. Each worker with the potential to exceed 10% of the quarterly radiation limits (essential workers who occupied a radiation zone, controlled area, radiological area, or whatever designation was in use at the time) wore, as a minimum, a dosimeter that recorded exposure. The radiation contributing to external dose was primarily beta and photon, including X-rays. Neutron exposure was not monitored, nor was monitoring required by regulation. Neutron exposure, if any, was below the measurement threshold of the dosimeters in use up through the mid-1980s (Nuclear Track, Type A Emulsion film).

Beta and Photon Characterization

The beta and photon radiations are well characterized in *Technical Basis Document for the Fernald Environmental Management Project (FEMP) – Site Description* and in the *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational External Dose* and cited references (ORAUT-TKBS-0017-2 and ORAUT-TBKS-0017-6). Table 5-5, Default Photon Energies for FMPC Materials, summarizes the nominal photon energies for materials present at FMPC. The beta radiation spectrum ranges from low energy to high energy. Technetium-99, a contaminant in recycled uranium and many of the uranium and thorium progeny, contribute to the low energy beta spectrum. Protactinium-$234^m$, a decay product of uranium-238, is a major contributor to high energy beta emissions and has a maximum beta energy of 2,281 keV. Penetrating dose rates have been documented to range from environmental levels (a few microrem per hour) to hundreds of mrem per hour in rarely occupied or inaccessible areas. A better estimate on the maximum penetrating dose rate in occupied areas is 10 to 20 mrem per hour.

Neutron Field Characterization

No measurements of the neutron energy spectra at FMPC have been discovered. Empirical knowledge documented in *DOE Standard: Health Physics Manual of Good Practices for Uranium Facilities*, indicate that the majority of neutron energy occurs in the 100 to 2,000 keV range (DOE-STD-1136-2000). A few neutron dose equivalent rate measurements have been documented (ORAUT-TBKS-0017-6, page 18). For depleted uranium in green salt (uranium fluoride) form, the average rate was 0.076 mrem / hour. For low enriched uranium, ranging from 1.25% to 2% enrichment, the dose equivalent rate from green salt was 0.107 mrem per hour.

7.3.1.2 History of Whole Body External Monitoring

Historical data describing the external monitoring of exposures are documented from start-up to present in *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational External Dose* and cited references. From the beginning of operations, the site mirrored model radiation protection dosimetry programs established at other weapons complex sites. The Oak Ridge National Laboratory film dosimeter was used until late 1985 when it was replaced by the FMPC thermoluminescent dosimeter (TLD) system. In 1987, this dosimetry system, that is the dosimeter, reader, calibration, and record management practices, became the first TLD system certified by the DOE Laboratory Accreditation Program (DOELAP). This accreditation continues to be maintained through periodic recertification conducted by outside organizations.

There were documented periods of time when certain classes of workers were not monitored based on the judgment of the radiation safety staff that they were unlikely to receive an external dose in excess of 10% of the quarterly limits. Because females did not work in production jobs between 1951 and 1960, and then again between 1969 and 1978, only male employees were monitored for external dose. During other operational and post-operational periods, both male and female employees may have been monitored. Providing that the individuals maintained the same or very similar positions during the time periods in question, adequate data, preceding and following the given periods and/or preceding and following monitored exposures, are likely available to fill in any gaps for individuals with gaps in their exposures records. The default annual dose value for unmonitored employees has been set at 500 mrem in *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational External Dose* (ORAUT-TBKS-0017-6).

#### 7.3.1.3 History of Extremity Monitoring

There is no site specific and complete history of the extremity monitoring program. However some data is available in *FEMP External Dosimetry Program Development* and in *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational External Dose* (Cooper, 1998 and ORAUT-TBKS-0017-6). Extremity dosimetry was calculated using a wrist dosimeter measurement and a correction factor. Early worker exposure records provide some evidence that a correction factor of three may have been used. However, documentation of a correction factor was not established until a study described in the document titled *FEMP External Dosimetry Program Development*, determined that a factor of 2.06 times the wrist dosimeter value should be used to estimate the dose to the extremity. The wrist dosimeter in use at the time of the study was a Teflon disk embedded with CaSO4:Dy. However, records indicate that film previously had been used at the FMPC. Because the wrist dosimeter is worn outside of any protective clothing and worker extremities were shielded by protective clothing (e.g. gloves), the method of using a wrist-to-finger ratio may overestimate the extremity dose by as much as 20%. Therefore, the recorded extremity doses should be claimant favorable.

#### 7.3.1.4 Neutron Dosimetry Study and Dose Reconstruction

Both the text and references of *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational External Dose* contain the data used to develop a neutron-to-photon ratio to estimate neutron dose for workers in certain facilities where neutron dose was likely. In these cases, the neutron dose was a small fraction (nominally 10% to 20%) of the penetrating photon dose. The neutron-to-photon ratio used to establish neutron dose varies depending on the nominal uranium enrichment during the period of interest. For depleted uranium, the geometric mean of the ratio is 0.07 and the 95th percentile of the distribution is 0.17. For low enriched uranium, the geometric mean of the ratio is 0.10 and the 95th percentile of the distribution is 0.23. To simplify the dose reconstruction process and ensure claimant favorability, NIOSH assumes that the higher ratio value, which is associated with low enriched uranium, is used. These data, coupled with the individual's dosimetry record, enable reconstruction of neutron dose. If a worker's facility history cannot be determined from the individual's records, then neutron dose will be assigned based on the photon dose.

#### 7.3.1.5 Dosimetry Records

As is detailed above in Section 6.2, data and documents covering external dosimetry and related records covering the entire operational period of the FMPC are readily available.

#### 7.3.1.6 Application of Co-Worker Data for External Dose Reconstruction

Since nearly all of the FMPC workers were monitored for external radiation, no co-worker studies have been performed.

### 7.3.2 Ambient Environmental External Radiation Doses at FMPC

An evaluation of ambient environmental external radiation doses is not necessary because this dose is accounted for in the process-related external dose evaluation referred to in Section 7.3.1 of this evaluation.

### 7.3.3 FMPC Occupational X-Ray Examinations

As part of the requirements for FMPC employment, entrance, exit, and periodic physical examinations were performed on employees. These physical examinations typically included radiographic examinations of the lungs. For some employees, such as construction workers and laborers, lumbar spine X-rays may also have been taken. Photofluorographic X-rays are not known to have been performed at the FMPC (ORAUT-TKBS-0017-3, Section 3.2).

Chest X-rays from the years 1952 to 1981 were performed annually for all employees. From 1981 through 2002, employees over the age of 45 had annual chest X-rays while employees under 45 years of age were offered a chest X-ray every two years. The retake rate of the chest X-ray is estimated at 15% (ORAUT-TKBS-0017-3, Section 3.2).

### 7.3.4 External Dose Reconstruction

Through September 14, 2006, 690 claims from FMPC workers had been submitted to NIOSH. Of those 690 claims, dose reconstructions have been completed for 619 claims. These claims cover the entire range of operation at FMPC with 93% of claims having external monitoring data available.

There is an established protocol for assessing external exposure when performing dose reconstructions (these protocol steps are discussed in the following subsections):

- Photon and Beta Dose
- Neutron Dose
- Unmonitored Individuals Working in Production Areas
- Medical X-ray

#### 7.3.4.1 Photon and Beta Dose

Each worker in a radiation zone, controlled area, radiological area, or whatever designation was in use at the time, as a minimum, wore a dosimeter which recorded radiation exposure. The radiation that was present at FMPC was primarily beta and photon, including X-rays. By considering the energy distribution and quantities, along with corrections provided in Section 6.3, Section 6.5, and Section 6.8 of *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational External Dose* (which provides corrections for radiation energies less than 250 keV, and dosimeter bias and uncertainty), these considerations should account for any discrepancies in photon and beta radiation doses received at the site.

The recommended procedure for missed photon and beta dose is to use a log normal distribution, with a median /central tendency equal to the Limit of Detection (LOD)/2 * (the number of zero measurements) and LOD * (the number of zero measurements) as the upper 95% estimate.

#### 7.3.4.2 Neutron Dose

Neutron exposure was not monitored, nor was monitoring required by regulation. The only likely sources of neutron exposure were those areas of the site where large quantities of fluorinated uranium compounds, such as uranium fluoride or uranium hexafluoride, were processed or stored. A neutron-to-photon ratio has been developed to assign neutron dose to employees based on work location and measured penetrating photon dose (ORAUT-TKBS-0017-6, Section 6.3.5.1).

#### 7.3.4.3 Unmonitored Individuals Working in Production Areas

Although female workers wore a combined security and dosimeter badge, during specific times, female employees at the FMPC were not routinely monitored. Female employees were not monitored during certain periods because it was determined that the potential did not exist for females to exceed 10% of the quarterly standards, as they did not work in production areas. The guidance in *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational External Dose* recommends assigning unmonitored workers 500 mrem per year as an upper bound limit for the years female workers were not monitored (1951 through 1960, and 1969 through 1978). There may have also been other circumstances, over the operational period of the FMPC, where either male or female workers may not have been monitored. Since the 500 mrem value is several times above the mean doses observed for monitored workers, this value could be adapted for all unmonitored workers for all years.

#### 7.3.4.4 Medical X-ray

For dose reconstruction purposes, one annual chest X-ray procedure for each full or partial year of employment is assumed unless individual records suggest more frequent examinations. Hard copy records of X-ray exams, if performed, are included in the individual's dose record provided by the DOE.

A review of case records indicates that lumbar-spine X-rays were taken for some employees, but these X-rays may not have been for occupational or pre-employment purposes (ORAUT-TKBS-0017-3, Section 3.2). However, as a claimant-favorable assumption, if lumbar-spine X-ray records are identified in individual employee records, dose from lumbar-spine X-rays will be included in that individual's dose reconstruction. In addition, for best estimate dose reconstruction cases, any X-ray performed on a worker should be assessed by the Dose Reconstructors to determine why the specific X-ray was performed. If it is determined that the X-ray was potentially performed as a condition of employment, dose from that procedure will be included (ORAUT-PROC-0061).

To allow for dose reconstruction, Tables 3-13 through 3-19 of *Technical Basis Document for the Fernald Environmental Management Project (FEMP) – Occupational Medical Dose*, provide organ dose estimates for FMPC chest radiographs for the various years (1951 through 2004) of operation at the site. These doses vary by year depending on the type of equipment used and orientation of the subject, Posterior-Anterior or Lateral. The most claimant favorable dose may be selected when details of the actual examination are not known.

### 7.3.5 External Dose Reconstruction Feasibility Conclusion

Recorded external dosimetry data is extensive and sufficient for external dose reconstruction. NIOSH has established that it has access to sufficient information to either: (1) estimate the maximum external radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the external radiation doses to members of the class more precisely than a maximum dose estimate.

## 7.4 Evaluation of Petition Basis for SEC-00046

The following subsections evaluate the assertions made on behalf of petition SEC-00046 for the FMPC.

### 7.4.1 Evaluation of Major Topics Detailed in Petition SEC-00046

The following major topics were discussed in petition SEC-00046. Italicized statements are from the petition; the comments that follow are from NIOSH.

#### 7.4.1.1 Lack of Monitoring for Recycled Uranium (RU) Contaminants

SEC-00046 petitioner statements relating to the lack of monitoring for recycled uranium contaminants:

- *There was no monitoring for internal exposures for recycled uranium contaminants.*
- *Prior to 1989, there were no recycled uranium contaminants that were reported in analysis.*
- *In vivo counts were not performed frequently enough to be of significant value in transuranic dose reconstruction.*
- *There was no monitoring to detect transuranic contaminants with the Mobile In-Vivo Radiation Monitoring Laboratory.*
- *Before 1989, smears or air sampling filters were not analyzed specifically for plutonium, neptunium, or thorium isotopes.*
- *Non-uranium urinalysis was not performed.*
- *There was no monitoring for non-uranium radionuclides.*

Section 5.2.2 of *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational Internal Dose* provides an approach to account for missed internal dose from unmonitored or undetected recycled uranium impurity activities. This approach determines the uranium intake, and then (for intakes occurring after 1961) adds a claimant-favorable ratio of recycled uranium impurity activities to that intake. Since the chemical form of the contaminant is unknown, the dose reconstructor is also directed to use the most claimant-favorable uranium solubility type for the target organ.

For environmental internal dose reconstruction from recycled uranium contaminants, Table 4-10 of *Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational Environmental Dose*, derived from historical site releases, provides a site-wide intake of each uranium and each non-uranium radionuclide by year from 1951 through 2002.

#### 7.4.1.2 Lack of Monitoring for Thorium

SEC-00046 petitioner statements relating to the lack of monitoring for thorium exposures:

- *In vitro bioassays for thorium were not performed.*
- *Before 1989, smears or air sampling filters were not analyzed specifically for plutonium, neptunium, or thorium isotopes.*
- *Non-uranium urinalysis was not performed.*
- *There was no monitoring for non-uranium radionuclides.*
- *Thorium exposures may have occurred in areas other than areas included in Table 5-16 of ORAUT-TKBS-0017-5 (Default Thorium Exposure).*
- *How can a dose reconstruction be reasonably accurate when the exposure potential data is not inclusive for all production areas?*
- *A question that was not asked during thorium process history reconstruction interviews was: What other plants processed thorium? [That seems so basic, if you're reconstructing destroyed records].*
- *How is it claimant favorable to ignore a documented exposure?*
- *The fact that no default exposure allowance was attributed to Plant 6 from January 1960 to July 1963 indicates that it was not considered or included in the internal and external thorium exposure environment.*

The *Fernald Environmental Management Project Site Profile* default exposure approach is based on the review of air sampling results at the FMPC. Assumptions include not taking credit for standard respiratory protection factors, using an exposure period of 100 hours per year at an elevated airborne radioactivity level of 10 Maximum Allowable Concentration (MAC), as well as an exposure period of 500 hours at a level of 0.1 MAC. The default thorium exposures are located in Table 5-16 of *Technical Basis Document for the Fernald Environmental Management Project (FEMP) - Occupational Internal Dose* (ORAUT-TKBS-0017-5). Table 5-16 includes only specific periods for the Pilot Plant, Plant 8, and Plant 9. If a work location is not clearly known for a worker, they are assumed to have been exposed to thorium at the times listed in Table 5-16.

According to documents provided by the petitioner, as well as *Technical Basis Document for the Fernald Environmental Management Project (FEMP) - Occupational Internal Dose*, exposures to thorium may also have occurred in Plants 1, 4, and 6. These areas will be incorporated into Table 5-16 of the *Technical Basis Document for the Fernald Environmental Management Project (FEMP) - Occupational Internal Dose*.

The NIOSH position is that for any individual that indicates an exposure to thorium, the default intakes will be assigned. However, in light of new data, a more precise approach is being developed. As stated in Section 7.2, extensive MIVRML lung counting data are available from 1968 through 1979, with the associated air monitoring data during the same times (which are being expanded at the present time from further historical data recovery efforts). The extensive air monitoring data in the 1954 through 1955 and 1964 through1968 period will also be used to bound the exposures during those periods in which limited bioassay analyses are available for thorium.

7.4.1.3 Lack of Monitoring for Radium and Daughters

SEC-00046: *No records were found of any bioassay results for radium or daughter products during the time evaluated in this report.*

Starting in 1953, processing pitchblende ore and its associated waste resulted in exposures to radium and associated contaminants, including radon gas and its progeny. Radon breath analyses were conducted for workers handling radium bearing materials. Samples that were taken for the years 1952, 1953, and 1954 are available in the SRDB (Ref. IDs 3167, 3191, 3193, and 3197).

Section 5.2.4 of *Technical Basis Document for the Fernald Environmental Management Project (FEMP) - Occupational Internal Dose* (page 27 of 42) includes a maximizing approach to bound the exposure from K-65 silo operation. This method uses results of sampling performed in 1993. Also included in this section is a method to bound exposures from the radon and its daughters, which is based on the radon samples from October 29, 1953 (ORAUT-TKBS-0017-5). In addition to Section 5.2.4 of *Technical Basis Document for the Fernald Environmental Management Project (FEMP) - Occupational Internal Dose*, The Pinney study, which estimated exposure to all FMPC workers, may also be used to bound the doses to workers when sampling results are not available (Pinney, 2004).

7.4.1.4 No Personnel or Area Monitoring for Neutrons

SEC-00046: *There was no neutron dosimetry.*

The FMPC TBD makes reference to the FMPC policy that the facility did not require use of neutron dosimetry. However, it also states that large quantities of uranium fluoride and uranium hexafluoride were present onsite, creating the possibility of low-level neutron exposure via the alpha-neutron reaction from the uranium alpha particle and fluorine atoms. Section 6.3.5.2 of *Technical Basis Document for the Fernald Environmental Management Project (FEMP) - Occupational External Dose* addresses workplace neutron fields. The approach assumes claimant-favorable energies and uses the photon dose to account for neutrons by using the upper 95th percentile neutron-to-photon ratio of 0.23 (*Technical Basis Document for the Fernald Environmental Management Project (FEMP) - Occupational External Dose*, Table 6-10).

### 7.4.2 Evaluation of Specific Petitioner Statements in SEC-00046

This subsection presents specific affidavit statements made by workers on behalf of petition SEC-00046. The italicized statements are from the petition; the comments that follow are from NIOSH.

7.4.2.1 Respiratory Protection during K-65 Silo Processes

SEC-00046: *Doses* (During K-65 Silo Processes) *have repeatedly been based on airborne activity and have been calculated on the assumption that all workers were protected by respirators.*

Regardless of the TBD statement that respiratory protection was worn when K-65 Silo processes occurred, the maximizing approach to bounding K-65 silo exposure does not take credit for respiratory protection (ORAUT-TKBS-0017-5).

7.4.2.2 Internal Dose Not Assigned from Bioassay or Air Monitoring

SEC-00046 petitioner statements relating to internal organ dose not assigned from uranium bioassay or air monitoring:

- *The uranium urinalyses that were performed were based on chemical toxicity and not radiological toxicity. Therefore, no radiological uranium urinalyses were performed.*
- *Internal dosimetry was not introduced until 1986. Before DOE Order 5480.11 (89), bioassay data was not routinely used to estimate intake and internal organ dose.*
- *There was no routine air monitoring used to establish internal intake and exposure estimates.*

Pre-1989 exposure control at FMPC was based on chemical toxicity and assumed that it would be sufficient for radiological control as well. A urinalysis program at FMPC was established from 1952 on, with nearly all employees providing urine samples at their annual physicals. Workers with higher exposure potential were sampled weekly, monthly, or bi-monthly. The urine was analyzed for the total amount of elemental uranium in the sample by the fluorometric fusion process. Results of those analyses are given in units of milligram of uranium per liter, which can be converted to activity units using the specific activity of uranium. Before DOE Order 5480.11 (1989), there was no regulatory requirement to report organ doses from bioassay data. However, the data from the urinalysis sampling for uranium toxicity are available to perform the dose reconstructions.

Since the beginning of operations, air sampling was performed extensively at FMPC. Routine air samples were taken in every plant and operational area. The FMPC air monitoring program was used to prevent workers from exceeding uranium intake limits associated with chemical toxicity, but was not typically used to establish worker intakes. Workers were required to submit routine urinalysis samples to verify that the work controls established by the air monitoring program were adequate. (ORAUT-TKBS-0017-5, Section 5.3.2)

7.4.2.3 Fecal Sampling

SEC-00046*: Fecal sampling has never been part of the routine bioassay program.*

Fecal sampling was not typically used as part of routine monitoring at FMPC, but rather as part of a special study or incident investigation. Since uranium is present at varying levels in the environment, and thus is present in food and water, fecal sampling is less than reliable for routine monitoring.

7.4.2.4 Falsification of Data

SEC-00046: *Air samples were manipulated to obtain desired readings and to give the appearance that radiation exposure levels were much lower than they actually were.*

A petitioner-supplied affidavit states that air sample results were manipulated. The applicant also submitted a document stating that the FMPC knowingly calculated effluent releases using a method which was flawed and grossly underestimated the releases. NIOSH could not find additional information corroborating that air monitoring was manipulated, nor do the FMPC technical basis documents specifically address this topic. While it is possible that air monitoring results were manipulated, this practice was unlikely to have routinely occurred, and since NIOSH will not be relying on a single air sample result to estimate a worker's intake (but rather a distribution of or compilation of multiple air dust measurements), it is unlikely that this practice would have a significant affect on an individual's dose.

### 7.5 Other Issues Relevant to the Petition Identified During the Evaluation

Note to OCAS: This section will be developed from issues that come up from SC&A and the Board.

### 7.6 Summary of Feasibility Findings for Petition SEC-00046

This report evaluates the feasibility for completing dose reconstructions for employees at FMPC from January 1951 through December 1989. NIOSH found that the available monitoring records, process descriptions and source term data are sufficient to complete dose reconstructions for the proposed class of employees.

Table 7-4 summarizes the results of the feasibility findings at FMPC for each exposure source during the time period January 1951 through December 1989.

**Table 7-4: Summary of Feasibility Findings for SEC-00046**

January 1951 through December 1989

| Source of Exposure | Reconstruction Feasible | Reconstruction Not Feasible |
|---|---|---|
| Internal | X | |
| - Uranium | X | |
| - Thorium | X | |
| - Other radionuclides (e.g. POOS nuclides, radon, and thoron) | X | |
| External | X | |
| - Gamma | X | |
| - Beta | X | |
| - Neutron | X | |
| - Occupational Medical x-ray | X | |

As of September 14, 2006, a total of 690 claims have been submitted to NIOSH for individuals who worked at FMPC during the years identified in the proposed class definition. Dose reconstructions have been completed for 619 individuals (90%).

## 8.0 Evaluation of Health Endangerment for Petition SEC-00046

The health endangerment determination for the class of employees covered by this evaluation report is governed by EEOICPA and 42 C.F.R. § 83.13(c)(3). Under these requirements, if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. Section 83.13 requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of class members when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for a number of work days aggregating at least 250 work days within the parameters established for the class, or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

NIOSH has determined that internal and external doses can be estimated with sufficient accuracy using the available bioassay data, dosimetry data, and knowledge of the source term at FMPC. Our evaluation determined that it is feasible to estimate radiation dose for members of the proposed class with sufficient accuracy, based on the sum of information available from available resources. A modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is not required.

# 9.0 NIOSH-Proposed Class for Petition SEC-00046

Based on its research, NIOSH accepted the petitioner-requested class to define a single class of employees for which NIOSH can estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all employees of DOE, DOE contractors, or subcontractors who were monitored or should have been monitored while working at all locations at the Feed Materials Production Center (FMPC), in Fernald, Ohio, also known as the Fernald Environmental Management Project (FEMP), from January 1, 1951 through December 31, 1989.The class was accepted because it encompasses all workers from the beginning of operations of the Pilot Plant until the time when the more stringent dose monitoring and reporting standards requirements of DOE Order 5480.11, *Radiation Protection for Occupational Workers*, governing the radiological control program went into effect (January 1, 1989).

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded accordingly (see Section 7.4). NIOSH has also reviewed available technical resources, and many other references, including the Site Research Database (SRDB), to locate information relevant to SEC-00046. Additionally, NIOSH reviewed its dose reconstruction database (the NIOSH OCAS Claims Tracking System (NOCTS)), to identify dose reconstructions under EEOICPA that might provide information relevant to the petition evaluation.

These actions are based on existing, approved NIOSH processes used in dose reconstruction for claims under EEOICPA. The guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science. Simultaneously, uncertainties in the science and data must be resolved to the advantage, rather than to the detriment, of the petitioners. When dose information is not available, or is very limited, NIOSH may use the highest reasonably possible radiation dose, based on reliable science, documented experience, and relevant data, to determine the feasibility of reconstructing the dose of an SEC petition class. NIOSH contends that it has complied with these standards of performance in determining that it would be feasible to reconstruct the dose for the class proposed for this petition.

# 10.0 References

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42 C.F.R. pt. 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule; May 2, 2002; SRDB Ref ID: 19392

42 C.F.R. pt. 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule; May 28, 2004; SRDB Ref ID: 22001

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